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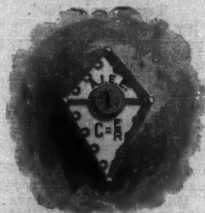
TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.



CONTENTS.

	PAGE.
Rail-Bonding, and its Bearing on Electrolytic Corrosion. (Illustrated.) A Communication by George. P. Low....	113
Notes on Recent Electrical Engineering Development in France and England. By H. Ward Leonard, Feb. 27th, 1895	129
OBITUARY.	
Franz Schulze-Berge, Ph.D	147
Alexander H. Bauer	148
Rudolf Elckemeyer	150
Macfarlane on Units of Light and Radiation, Discussion at Chicago, Jan 16th, 1895	152
Adams on Field Magnet Frames, Discussion at Chicago, Jan. 16th. 1895	154
Vol. XI., 1894, Notice	156
Death Notice	156
Advertisements	157

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RAIL-BONDING, AND ITS BEARING ON ELECTROLYTIC CORROSION.

BY GEORGE P. LOW.

[*A Communication in Discussion of a Paper, by Isaiah H. Farnham, on the Destructive Effect of Electrical Currents on Subterranean Pipes, read April 18th and 25th, 1894. See TRANSACTIONS, April, 1894.*]

Investigations into the characteristics of electrolytic corrosion of underground metal work by the earth return currents of electric railway circuits, and the methods suggested for remedying the troubles therefrom, lead to the conclusion that the problem of electrolytic corrosion and of rail-bonding electric railways may best be considered conjointly, for in the solution of one, may be found that of the other. The conditions of the many electric railway systems I have examined on the Pacific Coast, demonstrate that in such roads electrolytic corrosion is evidenced when the return circuit is in one or more of the several conditions soon to be described.

As explanatory of the terms used, the word "main" refers to the water main, gas main, Edison tube, telephone or telegraph cable, or the other underground metal structure that may be affected. In compound words consisting of two nouns connected by the preposition "to," a noun appearing first indicates that it represents a positive polarity, as in the expression "main-to-track-bonding," the bonding is between a positive main and a negative track. Conversely, "track-to-dynamo-bonding" indicates that a track having a positive polarity is bonded to the negative side of the dynamo. All generators are assumed to feed positive to line. By "cross-bonding" is meant the bonding between main and track without reference to the polarity of either.

The several conditions referred to as causing electrolysis, and which describe actual cases, are as follows:

1. When the track conductivity is low.
2. When the track is bonded with various points of mains

without regard to the polarity of the main or track, and is poorly bonded or not bonded with the negative of the dynamo.

3. When mains connect one portion of a track to a distant portion, there being no proper cross-bonding.

4. When the mains show positive potentials at one or more locations, there being no main-to-track or main-to-dynamo bonding at such points.

The preceding present the ordinary conditions conducive to aggravated forms of electrolysis, all of which may be summed up, though less distinctively in the single declaration that *corrosive*



FIG. 1.

electrolysis occurs when a main shows a positive potential at any point, without proper main-to-track or main-to-dynamo bonding:

5. When the track is not bonded to main or dynamo, there being only main-to-dynamo bonding.

This case is significant in that it exhibits an electric railway system which shows unusual considerations for the interests of a water company, to the material detriment of the coal pile of the former.

6. When the track is intimately cross-bonded with mains throughout, without regard to the polarity of either main or

track, there being no track-to-dynamo or main-to-dynamo bonding, and ground plates only being used.

The importance, not to say enormity, of Case 6, is shown in a remarkable example of corrosive electrolysis that was uncovered in the writer's presence. In a certain lighting and power station situated off the line of the railway system, an earth return was used exclusively, in order to avoid the expense of carrying negative feeders out to the track. Ordinary ground plates proving inadequate a two in. iron pipe with a No. 0000 wire inside, was driven to a depth of about ten feet to the water line under the station, and a second No. 0000 wire was carried out to the river

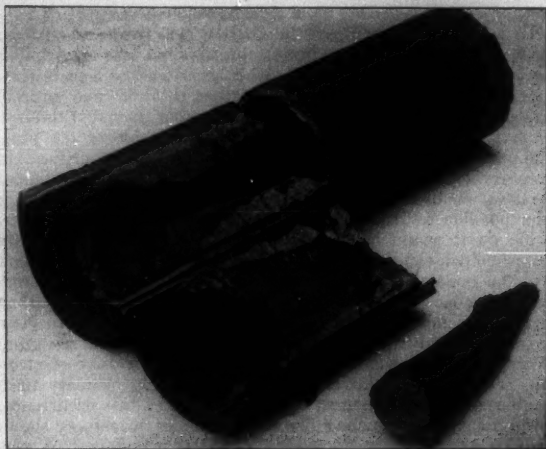


FIG. 1a.

several hundred feet distant and sunk, with some 40 feet of bare wire attached. This being still inadequate, a No. 0000 wire was attached to a six in. water main running into the river, and which was independent from the city mains, when good results were obtained. The method of cross-bonding consisted in tapping $\frac{1}{2}$ in. tinned brass plugs into the cast-iron water main at intervals of 1600 feet over the entire system. Four strands of No. 4 wire or two strands of No. 0 wire were used in this cross-bonding. These wires were soldered to the plugs, and driven-bonded into the rails after the usual manner. In making alterations in the power-house last summer it was deemed advisable to

lower the height of an engine which rested upon a foundation probably 15 feet deep, the foundation consisting of one part of Portland cement to three parts of clean sand and five parts of broken stone. The engine was bolted down to this by means of six $\frac{3}{4}$ in. bolts, each about 4 feet long, each bolt being sulphur centered in a 2 in. iron pipe, $4\frac{1}{4}$ feet long, the pipe being set in the cement, the bolts projecting above. The whole foundation top was flushed with $\frac{1}{2}$ in. of sulphur, upon which the engine was placed. Upon removing the engine and chiseling off 8 in. of concrete it was found that four bolts were in prime condition. The fifth bolt which was out of the pipe center because of having been bent, was corroded on the side nearest the pipe to a depth of approximately $\frac{1}{2}$ in., while the iron it had lost was deposited in the form of a sulphide upon the inner side of this pipe. Figs. 1, 1a, show the condition of the sixth bolt as it was taken from the concrete. Parts of the interior of the pipe bear the familiar marks of electrolytic pitting, probably occasioned at a time when negative was fed to line. The fact that the bolt was entirely corroded through is evident, as is the further fact that the iron taken from the bolt is deposited upon the inside of the pipe. The photographs clearly show streaks or veins of impurities that were developed in the sulphur which, it would appear, presented the usual conditions favorable to corrosive electrolysis. Had it been possible to reach the lower end of the pipe, marked corrosion on it would have undoubtedly been found. Obviously the principal condition leading to this experience was the fact that the boilers, engines, steam fittings, and even the concrete foundation served as a path for the return current. That the current was making a frantic effort to reach the ground plate was evident, and it would be hardly possible to find a more significant specimen of the insidious character of corrosive electrolysis, which is here proven capable of attacking ordinary inaccessible metal substructure. Having learned of this occurrence, the prudent station manager will see that his machinery shows absolute zero to the negative of his railway generators, or perchance some day his most trusted engine may gyrate through the station, causing ruin that would make a tornado envious.

In addition to the six conditions named, which are taken from actual experience, there yet remains a case that is as distinctive as it is perplexing. Both the corrosive action itself and the local conditions are so unusual that all details will be related. Fig. 2 is a map showing the location of the power-house and the affected water main, which consists of an 8-in. kalomine pipe under a street of a city, that is undoubtedly one of the most trying locations for underground iron work on the face of the globe. This is owing to the fact that the earth is almost saturated with a solution of sulphate of copper that seeps down from enormous copper mines on the hills, through the ground under the city. The avidity with which this solution attacks iron is

shown in the fact that the iron pipes used in pumping the cupric sulphate water out of the copper mines seldom lasted a month, until a preventive was found in lining the pipes with wood. Kalomine pipe withstands copper solutions better than cast or wrought-iron, but now an extraordinary trouble has appeared that seems to present a new and unrecorded form of corrosive electrolysis.

The map shown in Fig. 2, together with the explanation ac-

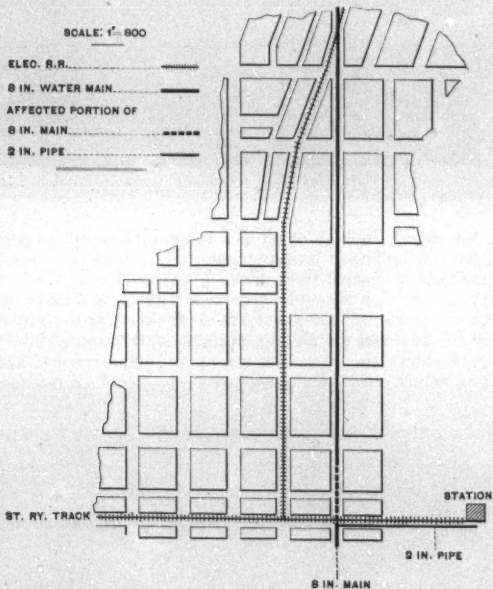


FIG. 2.

companying it, conveys all information necessary concerning the location of tracks, water main, the power-house, etc. The negative of the generators is grounded by two No. 0 wires, one to the track and the other to the 2-in. iron water pipe furnishing water to the station from the affected main. The affected portion of the 8-in. main referred to is about 300 feet in length, as shown on the map, and so serious is the action that its life seldom exceeds eight months. The peculiarity of the corrosion is in fact that the pitting invariably occurs on the inside, working outward.

Fig. 3 shows a photograph of the interior of a short length of this pipe within 22 in. on which are 18 perforations, all of the character described, and inside the pipe are clearly seen other pittings that have penetrated from within outward to various depths,

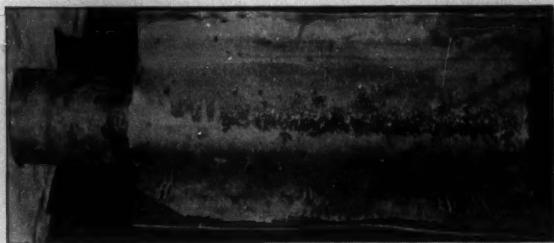


FIG. 3.

from the merest fraction of an inch to almost a complete perforation, also the sediment running longitudinally along the center that has been deposited from ordinary causes.

Fig. 3a exhibits the same specimen with the sediment on the right hand portion of the pipe scraped off, in order to show more clearly the fact that the pittings occur from the inside.

Fig. 3b shows the specimen set up and photographed against the sun, which proved the only way by which a satisfactory



FIG. 3a.

photograph of the perforations could be obtained. In one instance the sun being immediately in range, the perforation is greatly exaggerated.

Fig. 3c is from an inferior photograph of the reverse side of

the plate, which is in reality of a very smooth surface with many perforations.

A great deal of the same pipe is used throughout other por-



FIG. 3b.

tions of the city, but the internal pitting described occurs only on the 300 foot length defined. The exterior surface presents the usual rusted appearance, and in view of the opinion recently expressed by an eminent authority,¹ that the corrosion of nascent



FIG. 3c.

oxygen liberated by the electrolysis of water is not an effect of practical magnitude, it is difficult to assign any satisfactory cause

1. Prof. D. C. Jackson on "The Corrosion of Iron Pipes by the Action of Railway Currents," read before the Western Society of Engineers, July, 1894.

for the action. It has not been possible to obtain an analysis of the water in the pipe, but it is obtained from mountain streams 14 miles away and tastes pure and wholesome. Nor does it appear possible that the soil could affect the main internally. The fact that the trouble occurs at the point nearest the power-house affords circumstantial evidence against electricity, which is almost confirmed by the further fact that internal pitting and perforation is not to be found elsewhere in the city, even with the same pipe, water and other external conditions, excluding only the proximity of the power-house. It is for those having facilities for experiment to point out the action occasioning this internal corrosion and to indicate a cure.

Returning again to the usual forms of electrolytic corrosion, to relieve the main from injury, excepting that due to internal pitting and electrolysis at low conductivity joints in mains, it is advisable that the return current be confined to the track as closely as is possible. The most competent method of doing this in a double-track road, appears to be in an adaptation of the three-wire system, in which one trolley wire forms the positive, the other trolley wire forms the negative, and the rails forming the neutral. In this particular arrangement, which is different from those three-wire applications now in use in different localities, if the rails and tracks are properly bonded it is clear that under normal conditions the earth will be free from the enormous return current that at present seeks its way to the power-house by every possible channel.

Regardless of the carrying out of this eminently practical suggestion, however, electrolytic corrosion of mains from the earth return currents of electric railway circuits, will not occur when the following requirements have been complied with.

I. No cross-bonding at points where the mains show permanently negative potentials.

II. Heavy cross-bonding at points where the mains show permanently positive potentials.

III. Rail bonds of absolute permanence and reliability.

IV. High conductivity in track return circuit.

V. Greatest possible resistance from tracks and mains, at points where the mains show permanently negative potentials.

VI. Generators to permanently feed positive to line and negative to track and main.

VII. Heavy bonding between the negative side of generators to various proper points of mains not heretofore designated.

It is hardly necessary to emphasize the fact that trouble occasioned by corrosive electrolysis is largely due to the inadequate conductivity of the rail return circuit, or, to repeat the oft-told truth that the difficulty attending the use of the track as a return, is at the rail joint. The welding of rails is now believed to have reached the commercially successful stage, and it certainly forms a perfect construction in every sense, but up to the present, it

has not come into general use. Whether its slow development has been due to inherent defects or to demands for excessive royalties or other causes, has not been explained. A remedy may be found in another direction, and in looking for it the subject of rail joints must be thoroughly digested, not only electrically but from mechanical standpoints both in steam and street railways.

The method of joining together the abutting ends of rails is known as fishing, a term doubtless originated by Mr. Thos. Tredgold, one of the honored fathers of the profession of civil engineering, who defines fishing as perhaps the simplest and best method of joining beams. Continuing in the same strain Mr. H. Conybere, C. E., says:

"Of rail joints there are two varieties, the suspended and the insistent fish. The former has to perform two functions, the latter only one. The suspended joint had first to act as a girder by giving vertical strength to the joint between the two rails; the fishes therefore required to be long and deep as possible, to be fastened by four bolts, and to have the bearing edges as nearly horizontal, in order to keep the two ends of the rail in accurate opposition so that the joint might offer no obstacle to the smooth moving of the wheels. The insistent fish was not required to add to the vertical strength of the joint, such joint being supported by the joint sleepers or ties, the only function it had to fulfil was to maintain the extremities of the continuous rail in accurate opposition. For this purpose a much shorter and shallower fish than would be required in suspension, answered every purpose."

Another writer says:

"If rails were very deep the fish-joint would leave little to be desired. When a heavily loaded train is caused to run along a rail, it will be found to continually deflect under the insistent strain, and this deflection is transmitted onward in advance of the wheel, the rail assuming a curve in a vertical plane of greater or less length. When the wheel approaches a weak joint on a shallow rail, the curve is rudely broken. The stiffness of the joint principally depends on the section of the rail, often only a third of the stiffness of the joints is afforded as compared with the solid rail. Improved fish-joints give 80 per cent. of the stiffness of the solid rail."

Experiments made with two deep fish-plates having supports two feet between the centers of ties, and carrying a load of 25 tons shows more deflection on the solid rail than on the joint. The bolts were not the least hurt during the test. (Sandberg.)

A certain amount of elasticity is essential to the durability of the rails, which is the reason for the preference given to wooden ties. The compression of new ties under an engine, is found to be from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. sometimes with old ties. Besides the movement in the tie itself, there is also a movement of the tie

upon its bed, and these are the sole causes of the deflection of the rail. Considered as a beam to support an insistent weight, a rail of over 60 pounds per yard is abundantly able to stand up under five times the pressure that it will ever be called upon to bear. As regards deflection under a swiftly passing load, Mr. Bidder, President Institution of Civil Engineers, England, says, that if there was no rail in a space of three feet, at 40 miles per hour, the wheels of an engine would not deflect more than $\frac{1}{4}$ in. from gravity, therefore if a rail deflected more than $\frac{1}{4}$ in., no further pressure from the engine could occur. Capt. W. H. Taylor, another authority, expresses the opinion that when the rails are shallow, or are wanting in depth, the blows become serious, but when the section is deep and the ties are sufficiently near together, the deflection of rails under a passing load, is imperceptible. The most instructive expositions of the principles of track construction, are two pamphlets on "Smooth Track" from the pen of Mr. Philip Noonan of Troup, Texas, who is a pioneer in the advocacy of continuous rails and to whose researches is due much that is known concerning wave motion in the rails.

It is evident from the foregoing, that steam roads are designed to operate on a yielding roadbed, which gives from less than an $\frac{1}{4}$ in. to $\frac{3}{4}$ in. or more, as the train progresses, the train being continually preceded by a wave of depression. This is a feature that becomes marked in considering the points of divergence between the requirements of steam locomotive railroads, and street railroads. The latter is required to be operated at from 5 to 15 miles per hour; the routes they traverse are occupied jointly by all kinds of vehicles, hence the conditions are that these streets and highways shall be so paved as to support such traffic. This requires the placing of the top of the ties 6, 7, 8 and 10 inches below the surface of the street, and has necessitated the use of much heavier rails than those required on other lines of railway. When it is known that a rail is to be regarded as an iron beam, the stiffness of which is as the cube of its depth, the fact that the key for deriving a solution of the question of how to obtain a smooth line of rail has been reached, can be realized. The supported joint is preferable for street railroads because of the solidity and immovable character of the roadbed; the locomotive roads require the suspended joint so as to be in keeping with the elastic character of their roadbed. The difference between the two roads lies in the magnitude of the wave of depression passing along the rails under the traffic peculiar to each system. In the steam road the wave of depression is clearly defined and considerable; in the street road with its concrete bed and perfected construction if such wave exists at all it is negligible, and owing to the extreme rigidity of the joints; the abutting ends of rails certainly have no appreciable play. This is a point to be borne in mind.

The expansion of rails from increased temperature presents a

further point that has long been considered insurmountable, but recent experiments of great engineering value indicate the end of trouble from this cause. Mr. A. J. Moxham,¹ in experimenting upon a roadbed in actual operation, placed 1100 feet of 78-pound track in such a manner that it practically formed a continuous rail. The joints were made with the utmost rigidity, and many thousand temperature and other essential readings were carefully taken periodically day and night during the months that the experiment lasted. In Mr. Moxham's own words:

"The experiment proved absolutely and beyond cavil that the track is restrained and held by surface friction of the surrounding roadbed. From first to last, from a temperature 22 degrees below freezing point (or 10 degrees) to a temperature of 89 degrees above freezing point (or 121 degrees) there was absolutely no movement of the track out of place. Even at the ends this was true; proving that not only will the roadbed hold the track as a complete structure, but that it will do it consecutively. Once bedded, it will hold a rail 10 feet or 30 feet as well as one 110 feet. On this point there is no room for error."

A further experiment in this direction was made by Mr. Wason of Cleveland, who, in order to get as nearly as possible a continuous rail, put down 1000 feet of track, riveting the joints with red hot bolts put in by boiler makers, and placing the ends together as closely as possible, six rivets to each joint. It was just as straight after ten months as when first put down, the joints being absolutely imperceptible.

It is now clear that the deep rails being imbedded in a solid roadway, enables the engineer to defy the forces of expansion in the rails: he therefore prepares the ends so that they closely abut, and then double bolts, rivets or welds the joints so as to make a practically continuous rail. In the case of a steel rail buried in the earth, the necessary expansion on account of increase of temperature consists of a minute enlargement of the sectional area, thus following the direction of least resistance. A fruitful source of trouble on street railroads, has been the space unnecessarily left between the rail ends for expansion as practiced hitherto by steam roads. The wheels of electric motor cars and even cable cars soon pound these places sufficiently to cause considerable deflection. Another point which will assist in maintaining perfect steel lines for street railway traffic is to adopt the four-wheeled truck system, eight wheels under each car, the motor to be attached to the two axles nearest the center of the car. By this means, the forward wheels, being idlers, will carry forward the minute wave of depression to be further depressed by the driving wheel carrying the greatest weight. This will tend to preserve the perfect line.

In view of the numerous references at hand, one can not ques-

1. Proceedings 11th Annual Convention of the American Street Railway Association, Cleveland, 1892.

tion the fact that recent practices have made it possible to obviate two details of track construction that have hitherto been considered insurmountable in rendering rails electrically continuous, namely, extreme rigidity at rail joints and perfect control of the



FIG. 4.

longitudinal expansion of rails. The art of street railway building having advanced sufficiently to enable the construction of mechanically perfect rail joints, the problem of using the rails exclusively for the return circuit may now be attacked without fear of failure from the difficulties attending either bonding or corrosive electrolysis. To comprehend the importance of the return circuit problem, it is instructive to carry out a line of reasoning that has appeared in a communication published in the *Street Railway Review*. "In steel rails" the article states, "it is usual to say that every 10 lbs. weight per yard means one square in. of cross-section. Four rails of 70 lbs. per yard = 28 square inches in section = a steel bar 4 in. x 7 in. = a copper bar 1 in. x 5 in."

The conductivity of a copper bar having an area of 5 square inches is equal to that of 38 No. 000 B. & S. wires. If, therefore, the four 70-lb. rails of a double-track system were electrically continuous and carried current at a density equivalent to 1000



FIG. 5.

amperes per square inch of copper, they would carry 5000 amperes a distance of one mile with a loss of but 88 volts, or less than 15 per cent. if the initial E.M.F. is 600 volts, or 16 per cent. if it is 550 volts, or 17.6 per cent. if it is 500 volts. This is a loss in

potential of less than 1.8 volts or $\frac{36}{100}$ of one per cent. per 100 amperes per mile. The attainment of these results by the electric railways of the country would mean an annual saving of many thousands of dollars.

The communication referred to concludes by defining the following conditions as affording the best return circuit.

- "1. Intrinsic resistance low enough to need no help from the earth.
- "2. Utilization of rails as return conductors.
- "3. Rail bonds of heaviest practicable size.
- "4. Rail bonds of shortest possible length.
- "5. Rail bonds protected against corrosion.
- "6. An underground main or trunk return from the powerhouse to the track, and there connected with each line of rails,



FIG. 6.

"and low enough resistance to carry the maximum current with but slight drop in potential."

It will be conceded that these conditions are thoroughly comprehensive and that their correctness is more apparent than is a means for their accomplishment, but to Mr. Frederick T. Newberry, a well known civil engineer of the Pacific Coast is due the credit of devising a method of bonding that so completely satisfies every possible condition in a thoroughly practical way, that only in extraordinarily large systems will the trunk return be necessary. This method is termed "direct bonding," and in it the bond consists of merely a copper dowel that is shrunk-fit into holes drilled into the abutting rail ends. The bond is formed by reaming out holes in the ends of the rails to be coupled one in the head and one or more in the bottom flange, as shown in Figs. 4 and 5. For a 70-pound rail the preferred diameter of the holes

is $\frac{5}{16}$ in. These holes are to be bored just before placing the rail, which is then heated by a gasoline torch and a round bolt or dowel of pure soft copper, two inches long and slightly larger than $\frac{5}{16}$ in. in diameter is driven in one rail. Then the abutting rail is forced upon the other end of the dowel, the faces of the rails being brought as closely together as possible. The fish-plates are then placed and double-bolted, riveted or welded together. The carrying capacity of these two dowels would be equal to one-half that of the rail, or equal to a bar of copper $\frac{1}{2}$ in. wide by $1\frac{1}{2}$ in. thick, which is amply sufficient to carry the return current of any road now in operation in this country. If it were found advisable to double this capacity, it would be done with three dowels, one of $\frac{7}{8}$ in. in diameter in the head, and two of $\frac{5}{8}$ in. in diameter in the bottom flange. The junction of the copper and steel in the interior of the rail is electrically perfect, and remains so as long as the rail continues in place. When the work is well done, no particle of copper will be exposed to any action from air, water or other agencies, and being completely enveloped in the rail will be perfectly protected from fracture or harm of any kind.

The connecting surface of this bond is seven times its area, thereby affording the rail a carrying capacity at the point of bonding equal to that of the bond itself, and with rails 30 feet long, 352 joints per mile, 70 pounds of copper will be consumed in bonding a single-track mile. Experience proves that no great heating of the rail is required to effect an immovable grip on the copper dowel, which is polished and placed in the freshly bored hole in the rail end that has been heated at so low a temperature that there is not the slightest oxidation. Additional rigidity is secured by rendering the dowel ends slightly conical, so that they are upset in being driven home. A sectional view of the dowel bond is shown in Fig. 6, consisting of two cubes of steel, each $1\frac{1}{2}$ in. on the side into which a $\frac{5}{8}$ in. copper dowel has been shrunk-fit. It does not appear that a more perfect union could have been made even by welding. According to Crosby and Bell, the cost of single No. 0 bonding is \$600 per mile, viz., \$400 for material and \$200 for labor per mile of single track. The cost per mile for boring and setting direct bonding having a carrying capacity of 600 amperes is estimated at \$150. Adding a royalty of 50 cents per joint, makes a total cost of \$326 per mile of single track, while with $\frac{3}{4}$ in. dowels having a carrying capacity of 800 amperes, the total cost is estimated to be \$400 per mile. Among the advantages of direct bonding will be enumerated:

- 1st. The practical elimination of the factor of length in bond wires.

- 2d. The use of bonds of maximum cross-section.

- 3d. Most perfect means available for effecting electrical contact between bonds and rails, hence

- 4th. Highest possible conductivity in bonding, and
- 5th. Absolute permanence.
- 6th. Perfect protection against water, acids, alkalies, gas, atmospheric or other corrosive influences.
- 7th. Minimum consumption of copper in bond wires (approximately 70 lbs. per mile at 15 cents per lb., \$10.50).
- 8th. Carrying capacity limited only by that of the rail.
- 9th. No cross track bonding.
- 10th. No supplementary bonding.
- 11th. No rivets, solder, paint, screws, bolts or channel pins.
- 12th. No electrolysis.
- 13th. Practical equivalent of welded rails from almost every standpoint.
- 14th. Easily attached to finished systems at a
- 15th. Cost not exceeding that of present methods of bonding, and at a
- 16th. Cost far less than that of welded rails.

A marked peculiarity in the operation of electric roads consists in the fact that for the same results in foot-pounds, electric roads require more than twice the boiler and engine duty that is necessary on steam roads. A brochure recently issued by a leading electric company states that although a ton weight may be moved on steam roads by an expenditure of force equal to a pull of eight pounds, which is the usual estimate, yet electric roads require for the same duty a steam and electric plant capable of exacting an effort of 30 pounds, this despite the fact that the line of track of a well-built electric road is far superior to that of steam roads in the true, even and immobile character of the rail surface. A perfect system of rail-bonding will effect an increase in efficiency of an electric road by various degrees of from 5 per cent. to 20 per cent., and the writer knows of at least one instance wherein perfect bonding would increase the efficiency of that particular system by not less than 25 per cent. It must be conceded, therefore, that a very material part of this extraordinary loss will be obviated by perfect rail-bonding.

A prevailing practice that might in generosity be termed an inconsistency, is that of bonding a wire to the web of a rail and then rating the carrying capacity of the bond as that of the wire. This fact suggests a criticism. A No. 0 B. & S. wire, for instance, has a circumference of 1.021 in., while the web of a rail is generally .375 in. in thickness. This multiplied by 1.021 and divided by 5.63, gives the carrying capacity of the rail surface exposed to the bond wire as the equivalent of a copper wire having an area of .068 square inches, or about 82 per cent. of the conductivity of the No. 0 bond. Under these generally prevailing conditions, the carrying capacity of such bonding is overestimated by about 20 per cent. To enable the copper bond to take a volume of current up to its full capacity, its surface contact with the rail must be roughly six times the area of the wire. It is obvious

therefore, that the web of the rail is not the proper place to attach bond wires.

To illustrate: the *Street Railway Journal* for January, 1894, contains this statement regarding the bonding of rails on the lines of the Electric Traction Company of Philadelphia:

"A bare copper No. 00 wire is used for electrically connecting the rails. This is laced in and out of the adjoining ends outside of the angle bars (fish-plates) three times, so that the carrying capacity of the bonds at each joint is three times that of a single No. 00 wire, and is equal to that of a 90-pound girder rail of the Pennsylvania Steel Company."

The fact is then, that the rails are triple lace bonded through the web with No. 00 wire. The bond wires alone, have a carrying capacity of 652 amperes at 122° F., but as they (being laced) make contact with the rails only by means of two holes in the web, the actual surface of steel exposed to the copper wire is but .859 square inches, whereas it should be at least 1.765 square inches to obtain the full carrying capacity of the three No. 00 wires used. From this it is evident that the bond will carry but one-half the current claimed, but after theory and practice have compromised the case, it may be found that the duty actually performed will approach the designed duty to within 20 per cent. or 25 per cent. This will reduce the advisable carrying capacity of the rail bond to less than 500 amperes. Again the statement quoted, claims that the carrying capacity of the bonding is equal to that of a 90-pound rail. The carrying capacity of a 90-pound rail is approximately 1500 amperes, against which 500 ampere bonding appears small, particularly in a system proposing to consume 10,000 horse-power. As scores of smaller enterprises anxiously await the lead of the great companies and follow implicitly in the same path, too much caution in publishing such statements as that quoted can not be exercised.

In conclusion, the art of rail-bonding now appears to have been perfected, and the damage that has been caused by corrosive electrolysis may be attributed to defective bonding, for without doubt proper main-to-track, rail-to-rail, and track-to-dynamo bonding will cure the ill almost without exception. Should the street railway companies delay in correcting the evil it is probable that municipal authorities will take action for the protection of citizens in their vested interests, in which event the conditions now existing may be further and seriously complicated by ill-advised municipal exactions. The problem of eliminating electrolytic corrosion is, in brief, simply one of judicious bonding.

San Francisco, Oct. 12, 1894.

[ADVANCE COPY. SUBJECT TO REVISION.]

NOTES ON RECENT ELECTRICAL ENGINEERING DEVELOPMENTS IN FRANCE AND ENGLAND.

BY H. WARD LEONARD.

INTRODUCTION.

As a result of inspecting some of the most interesting of the developments in the field of electrical engineering during a recent trip to France and England, and as a result also of having met many of the engineers responsible for these recent developments, I find it difficult to reach a conclusion as to whether we or our contemporaries across the water are ahead in the electrical engineering race.

Of course when one attempts to compare the electric developments of the respective countries commercially, we are in the same position as the "America" was in the historic yacht race, "there is no second;" but considering the recent electrical development from an engineering standpoint we are rapidly losing the lead we have thus far held.

Although I have always felt that so-called fundamental patents and the resulting enormous aggregations of capital and engineering talent under one management, were a millstone around the neck of our profession, I have never before had the opportunity of seeing positive and unmistakable evidence of it such as this visit abroad showed me.

In the beginning of electric lighting, both arc and incandescent, we led the world from an engineering standpoint, and were years ahead of any other country. But what has been done in this country in the way of a remarkable electrical engineering development since Edison started his first three-wire system at Sunbury, Pa., in July, 1888, and Westinghouse established his alter-

nating system with 1,000 volt primary and 50-volt secondary a few years later, and Sprague started the Richmond electric road? A moment's thought will, I think, make you all realize that the practical development of electrical engineering improvements is almost impossible against the opposition of the gigantic corporations in that field, and that corporations having such a large portion of their capital represented by patents will not wish to see the practical trial of a promising improvement which they do not control, and which may depreciate the value of the methods they control or claim to control. It is in just this way that we are losing ground when compared with England and France.

We undoubtedly have the best three-wire central station plants in the world, also the best alternating system converting from 1,000 to 50 volts. But what other kind of central stations have we to point to? Practically none.

We have 500-volt continuous current electric railways galore, and we operate such railways at distances for which 2,000 volts should be used instead of 500, and after investing more money in copper per car than the entire cost of the electrical equipment, we still lose twice as much energy as is commercial in the line.

Is there a large electric railway system in this country which as an electrical transmission of power is a credit to our profession? Not one.

In France, and even more in England, one is forcibly impressed by the many kinds of central stations being tried. Many of them may seem almost sure to prove commercially unsuccessful, but who can say which one may not prove the "Sunbury" of an enormous electrical engineering development?

No capital or patents can prevent the slow development of evolution, but I fear that under the existing conditions we shall have to content ourselves with drawing pictures of what might be done, and watch the continued introduction of the three-wire system of 1883, the 1,000 to 50-volt alternating system of about 1887 and the continuous current 500-volt railway system of 1887, while our engineering friends abroad keep trying not only their own ideas, but the ideas of many of us from this side because they have the necessary encouragement and opportunity to do so, while we have not.

I have learned on this hurried trip abroad of many applications of inventions of American engineers which have proven very

successful and which although patented, described and advertised in this country, were taken up first by English or French engineers notwithstanding their well known prejudice against American inventions.

ALTERNATING CURRENT PRACTICE.

In England one of the first things which impresses an engineer is the total absence practically of a 50-volt secondary for alternating systems. It is the general practice in England of late to use a three-wire secondary with 100 volts on each side. I believe that every engineer who has ever given the subject a thought, knows that there was no excuse except patents for a 50-volt two-wire secondary originally, and no excuse except the inertia and prejudice of large corporations for continuing to put in the two-wire 50-volt secondary to-day.

MANUFACTURING AND ENGINEERING.

In England there is a multitude of medium size concerns, manufacturing electrical apparatus, and the competition is mainly on ideas, and not the cost of dynamos per kilowatt. It is surprising to find that generators and motors are much cheaper in the United States than in either England or France, notwithstanding their advantages over us as to cheaper raw materials and labor.

The manufacturers abroad generally consider the consulting electrical engineers as entirely unnecessary in view of the multiplicity of schemes which every plant brings forth from the various manufacturers, but I believe that a great deal of benefit has been and is being accomplished in England, by virtue of the custom of placing in the hands of good consulting electrical engineers the design, for instance, of a large central station plant to be built by a city itself.

Has a central station of this kind ever been built in this country? I think not; that is, a central station built according to advice from a good consulting engineer who was free to select the good features and eliminate the bad features of the various systems known to the art. Imagine a central station combining apparatus and methods of the General Electric, Westinghouse, and Siemens & Halske all in one system, also taking advantage of other good ideas from the United States and abroad. Who can doubt that it would be better than could be built by using only the patents and apparatus controlled by some one company.

Many will answer that all the best engineers are in the employ of the leading companies and the consulting engineers available are incompetent commercially, and there is a great deal of force in this argument; but even if true, it certainly merely emphasizes the difficulty of getting a practical trial in this country of promising ideas in the electrical field unless they be controlled by one of the would-be-monopolists.

ROTARY TRANSFORMERS.

Rotary transformers are used in several stations in England for a continuous current high potential multiple arc distribution, the secondary being a three-wire system as usual. Such a plant is in use at Oxford. At Brighton and several other places the standard 220-volt continuous current three-wire system is supplemented for distant lighting and in newly occupied territory by the alternating system using about 2,000 volts in the primary, and a 220-volt three-wire secondary.

This alternating plant supplies the distant and scattered lighting during the period of heavy load, and during the period of light load (about three-quarters of the whole time) this distant lighting is supplied directly from the 220-volt three-wire system by switching the secondary circuit from the converter to the regular three-wire system.

Mr. Arthur J. Wright who installed this system first at Brighton, spoke of it to me as an American invention not patented in England, a description of which he had read in the American electrical journals, and was much surprised to learn that none of the central station companies had made use of it in the United States, as it was proving of the greatest value to him in his plant.

STEAM ENGINES.

I believe we are ahead of England and France in the designing of dynamos and engines. Their workmanship leaves nothing to be desired, but giving consideration to amount of material used, efficiency and design, I think we are in advance of them.

One of the most surprising things to me was to see the almost universal use of engines which we would consider had practically no governor. That is, engines using slow acting throttling governors instead of the triumphs of engineering skill which are so common in this country. Not since 1883 have I seen such

poor governors as I found generally used abroad in the finest and most recent stations, and upon engines which are almost perfection itself as regards manufacture.

THE PARSONS STEAM TURBINE.

The Parsons steam turbine was one of the most interesting things I saw in England. These steam turbines are direct coupled to dynamos, and in sizes of 350 k. w. revolve at 3,000 revolutions per minute, and of course run at higher speed in smaller sizes. The space occupied by a 350 k. w. outfit is over all about twenty-five feet long, five feet wide and including governor about seven feet high. These turbine plants when running at these high speeds are entirely free from vibration and are not even bolted down, but are supported by three pedestals, one near each end and one at the middle. There are some seven or eight bearings all in line, and a continuous stream of oil is forced through the bearings by a small pump driven by a worm on the main shaft.

The bearings used are extremely simple and very ingenious. The shaft runs in a gun-metal sleeve of about the usual dimensions, but between this sleeve and the surface of the pillow block are three cylinders of thin sheet brass concentric with the shaft, and sliding loosely over the gun-metal sleeve. The gun-metal sleeve is prevented from turning by a lug projecting down at one end into a hole in the pillow-block. The entire box being filled with oil, it will be seen that the shaft is free to vibrate slightly in every direction as it revolves, and that the viscosity of the oil tends to damp any such vibration. The three thin surrounding sleeves are perforated by a hole of about $\frac{1}{4}$ inch at about every two inches, so that the oil can work freely between these sleeves. The Parsons steam turbine uses the steam expansively as a reciprocating engine does. The steam at about 125 lbs., and preferably superheated, is led into the center of a cylindrical chamber in which the moving parts revolve. There are three of these chambers. In the first chamber the steam is expanded down partially, and thence goes to a second similar chamber and finally to a third one, which last chamber leads to the condenser. In each of these chambers the steam in its passage from the admission to the exhaust has to pass some thousands of small blades or teeth which project from the surface of the disks a fraction of an inch. The amount of steam used and its expansion, will de-

pend upon the clearance, and the number of these turbine disks it has to pass in getting to its exhaust. It will be evident that the friction of the engine is less than that of a reciprocating engine, and that the condensation losses should be less. Also full advantage can be taken of high pressure and especially of superheated steam, for the difficulties of proper lubrication and packing in the presence of high temperature steam in a reciprocating engine do not apply to this engine.

Tests by Professors Ewing and Kennedy indicate that this turbine when in perfect condition has an efficiency of one k.w. hour in electrical energy produced by 28 lbs. of feed water, the turbine being operated condensing. This is equivalent to about 15.7 pounds of water per indicated horse-power per hour, and I understood that in a recent competition a guarantee was made by Mr. Parsons which was equivalent to about 13 pounds per indicated horse-power per hour, and that his guarantee was lower than that of the best triple compound condensing engines of the reciprocating type which were in the competition. At Newcastle-on-Tyne I saw a central station of about 25,000 lights operated solely by these steam turbines, and which has been in operation since 1890 and has been earning and declaring dividends ever since it started. An interesting fact as to this Newcastle station is that all of the conductors are laid underground and consist of vulcanized rubber cables drawn into cast-iron pipes which are gas and water tight, and through which chemically dried air is forced from the station by a blower.

There are over six miles of piping and over 25 miles of cable, and after five years operation Mr. Parsons states that they have not had a single instance of failure of insulation, explosion or other trouble with the underground system.

THE LAVAL STEAM TURBINE

Before leaving the subject of steam turbines, I will describe the Laval steam turbine of which I saw a number in the works of the manufacturers, Breguet & Co. of Paris. This steam turbine differs radically from the Parsons. The power is derived from the momentum of a jet of steam impinging upon buckets near the periphery of a disk, so that the machine is somewhat comparable to the Pelton water wheel. The steam, which is preferably used at a high pressure and exhausting into a vacuum, is expanded in a nozzle before reaching the disk, and reaches the buckets of

the disk fully expanded, and hence moving at a very high velocity which the inventor claims is 3000 feet per second for steam at 85 lbs. per square inch, exhausting into the air, and 3700 feet exhausting into vacuum. The nozzle makes a very slight angle with the plane of the disk. The admission of steam is controlled by a centrifugal throttling governor. The number of revolutions of the disk per minute varies from about 30,000 to 15,000 in sizes from 5 to 50 horse power. The buckets are milled out of a solid disk of steel just inside of the periphery, so as to leave a solid band on the circumference. The edges of the buckets are quite sharp. The disk in a case of a 50-horse power turbine is about $\frac{1}{2}$ in. thick. This disk is mounted on a small steel flexible shaft at a point about $\frac{1}{3}$ from one end. At the high speeds in question, a body tends to revolve about an axis through the center of gravity, and since it is impracticable to make the center of gravity absolutely coincident with a straight line joining the bearings, Mr. Laval has used a flexible shaft so that the disk is free to assume such a position as to revolve practically around an axis, through the center of gravity, and consequently the disk revolves with perfect smoothness and without any trouble at the bearings at these enormous speeds.

No successful way has been perfected as yet for operating a dynamo directly at these speeds, and so Mr. Laval gears from his turbine shaft to two dynamo shafts, one on each side of the turbine shaft, by means of double helical gears beautifully cut, which reduce 10 to 1, and upon these two driven shafts are placed the dynamo armatures, two driven shafts being used so as to balance the side thrust on the bearing of the turbine shaft. The Laval people claim as high efficiency as that of any steam engine of the same horse-power, and there seems no good reason to doubt their ability to secure such an efficiency which they guarantee fully and specifically.

A careful test made at Stockholm in 1893, showed an efficiency of 20 pounds of water per horse-power hour with steam at 113 pounds initial pressure and used condensing. The weight of this turbine is about 30 pounds per horse-power in a size of about 30 horse-power.

The simplicity of this steam engine, also its theory and practical design in detail are most beautiful, and it seems likely to become an important factor in the electrical field. What is needed is a generator of electricity directly driven by, or preferably con-

stituting a part of, the revolving disk, and here is food for considerable thought.

FIVE-WIRE SYSTEM.

At Manchester I saw the five-wire plant designed by Dr. Hopkinson and recently installed. I inspected the central station for a few minutes only, as unfortunately those most familiar with the principal features of the system were absent at the time of my visit. The dynamos were bipolar machines driven from vertical engines by means of link belts with idlers. I cannot say that I was favorably impressed with the generating plans or distribution system, as far as I could judge of them in such a brief observation.

LIVERPOOL ELECTRIC RAILWAY.

At Liverpool I investigated the overhead electric railway. The overhead structure, the motors, methods of collecting the current, etc., were exceedingly well designed and constructed, and gave evidence of good working. The central station apparatus and design was not, however, up to the standard of work here in recent electric railways.

The series parallel control is used, but no rheostat, the designer seeming to realize that it might just as well be left out, and the equivalent resistance secured in the windings of the motors themselves, with less apparatus and no appreciable difference in economy or control.

ENGLISH CENTRAL STATIONS.

In London I visited several central stations of which I will mention two. The first is that of the Metropolitan Electrical Supply Co. This company has an enormous area allotted to it. I will explain right here, that both in London and Paris the authorities follow the plan of granting to several different central station companies—supply companies as they term them—the exclusive right to a certain section of the city. No such company can run into any other company's section. At the central station of the Metropolitan company, I found four Parsons steam turbine units of 350 k.w. each, running at 3,000 revolutions per minute. These steam turbines had been in operation only a short time when I saw them, and had been installed for the reason that the central station had been enjoined by the courts from operating the reciprocating

engines formerly in use because of the vibration they caused. I was informed that the vibration was particularly troublesome and difficult to overcome, because the central station was built upon made land, above the bed of a former river and that the ground was boggy and transmitted any vibration in the most surprising manner. I inquired as to the working of the steam turbines and was informed that they were not able to detect any difference in their coal consumption compared with the compound condensing reciprocating engines formerly in use. I found that an accident had happened to one of the steam turbines by which it had lost all of the blades in one of the three chambers, which reduced its capacity and efficiency considerably, but did not put it out of service entirely.

The other London central station I shall refer to, is that of the City of London Company. This company supplies the heart of London, that is the old "City of London," which is without doubt the best central station territory in the world, on account of the wealthy nature of the customers, the substantial character of the buildings, and especially because of the peculiarly dismal foggy weather in London. While I was there, artificial light was required almost as much by day as by night. This central station is beautifully located on the south bank of the Thames, near the center of lighting, and is a fine example of the best that can be done to-day with the alternating system under such conditions. I do not believe it would be possible to find less excuse for the use of the alternating system than in this station, and yet I expect it will pay, for it can hardly fail to earn money under such extraordinarily favorable conditions for lighting.

But I need hardly say that they have no motors except toys, and but few of them; and when I remember that in Chicago 40 per cent. of the connecting load is motors and that this percentage is rising all the time, it seems evident that the City of London Co., is terribly handicapped by the use of the alternating current. However, they have a 2,000-volt three-wire secondary, and operate the dynamos all on multiple-arc which is certainly using the alternating current to the best advantage. Aside from the use of the alternating current under these conditions, it is difficult to say anything in criticism of the central station.

The plant is arranged on the panel system, which Mr. Mordey says originated with him, and which is thoroughly carried out in this station, for each panel or section across the building com-

prises an independent unit including a boiler, engine, dynamo, and switchboard for 500 k.w. The engines are vertical and direct-coupled to the Mordey alternators. The switchboards are entirely novel in design, being cast-iron pyramids about ten feet high, standing clear from the wall and having all of the conductors inside, with the instruments, etc., mounted on the front face. While very finely finished and ornamental, I could not but think that the vital parts would be more difficult to inspect and repair in case of emergency, than in our recent switchboard practice.

One detail of electrical construction in which the foreign practice seems very backward is the rheostats. In this magnificent station in the City of London, for instance, and in many other places I saw rheostats made by winding german silver wire on a slab of slate, which was then mounted on insulators horizontally on a table, and a slider arranged to move over the surface of the resistance wire itself, which was thoroughly exposed.

Another detail in which we are certainly in advance of foreign practice is our instrument work, for which we must thank Mr. Weston solely. I saw many fine instruments while abroad, but they seemed to be more suited for a physical laboratory than a central station, the substantial compact permanent features of the Weston instrument, with its readable scale and dead beat index were conspicuous to me by their absence.

FRENCH CENTRAL STATIONS.

In France the most interesting central station I saw was in Paris where I visited a sub-station designed for a capacity of 30,000 lights. The sub-station was supplied from a distant central station by means of a constant current of 250 amperes, all devices on this current being in series and the total E. M. F. running as high as 6,000 volts at times.

In the sub-station were rotary transformers, the primary ends of which were series wound motors and all being in series. The secondaries of these rotary transformers as generators, fed a five-wire system of conductors, and in multiple-arc with these generators across the five-wire system, was a bank of storage batteries. The lamps used were 110 volts; some of the rotary transformers had 110-volt secondaries, four of such secondaries being in series so as to make the five-wire system complete independently of the batteries. Other of the rotary transformers had 440-volt

secondaries and fed the outside conductors only. On each rotary transformer was a rheostat which was in multiple with the series wound field and which by a step-by-step movement similar to that of the old U. S. automatic regulator, controlled the strength of the series field so as to keep the E. M. F. in the secondary, constant; the controlling magnet of the automatic being across the secondary of constant E. M. F.

The storage battery plant was well designed and seemed to be in good order. It was as clumsy and seemed as full of troublesome possibilities as those we have on this side of the water. It had capacity for 8,000 10 c. p. lamps for three hours and cost about \$30,000, weighed about 400,000 pounds and occupied a space about 32 x 50 feet. This cost means about \$107 per k.w. of output which seems a pretty high price to pay for a plant to generate electrical energy to-day, especially when it probably has an efficiency at three hours' discharge not above 60 per cent. Such a storage battery must be compared in cost with the cost of boilers, engines and dynamos per kilowatt, which would cost perhaps \$50 per kilowatt, and whose efficiency would be 100 per cent. as compared with the 60 per cent. efficiency of the storage battery, since the storage battery must derive its energy from a steam plant first. The craze for storage batteries as the universal panacea for electrical troubles which we have all read so much about in connection with European practice, seems to be on the wane, if I may judge from the statements of the engineers, rather than the storage battery manufacturers, but when we remember that in France and England they do not know what a healthy motor load means, we need not be surprised at the claims of inefficiency for stations which do not use batteries, and hence run their boiler, engine, and dynamo for most of the 24 hours practically without load.

IMPORTANCE OF THE LOAD FACTOR IN CENTRAL STATIONS.

All central station people have known for years that the most profitable consumers were those who used their lamps for the greatest number of hours.

In other words, that the net profit due to a consumer was largely dependent upon the relation between his average load and his maximum load, which Mr. Crompton in England has aptly called the "load factor." Yet, while appreciating this fact, central station companies make their rates dependent upon the

kilowatt hours used, and independent of the maximum kilowatts used.

Mr. Arthur Wright at Brighton in England, deserves the credit, as far as I know, for having first given commercial recognition to this load factor of the consumer. Mr. Wright supplies each consumer not only with a meter which registers the kilowatt hours used, but also a second meter of simple construction which registers the maximum kilowatts used at any time during the month, and the discount which the consumer gets is very largely due to the relation between his average and his maximum kilowatts.

Suppose that there are two customers connected to a central station and that the monthly readings show that each has used 900 kilowatt hours. By the usual practice in this country the bill would be the same, yet one bill may be due to the use of one and one-quarter kilowatts for 24 hours per day, and for 30 days per month, and the second bill may be due to the use of 30 kilowatts, an average of one hour per day for 30 days per month. That is, the first bill may be due to a steady load, such as a few lamps in a basement of a hotel or a ventilating fan, while the second bill may be due to a larger load of lamps used only occasionally, as in an office building or an electric elevator requiring 30 k.w. for a few seconds to start it up, and after starting requiring only 15 k.w.

With the same 900 k.w. hours per month for the two cases, the central station company should charge at least five times as much for the case having the elevator and small load factor, as in the other case.

It is a fact not generally appreciated that in any central station the cost of producing a kilowatt hour can be divided into two portions, one of which, such as interest on cost, depreciation, salaries, a small part of the labor and coal, vary with the kilowatt capacity of the plant, that is proportionately to the maximum load, and are independent of the number of kilowatt hours produced, and the other portion of the cost of producing 1 k.w. hour represented by the larger portion of the coal, labor, water, etc., is dependent upon the number of kilowatt hours produced, and is independent of the maximum load.

The fact about this matter which is best appreciated is, that the portion of the total cost of 1 k.w. hour produced, which depends upon the maximum load, is about two-thirds of the

total cost, and the part dependent upon the output is only about one-third.

In a modern central station 1 k.w. of its capacity represents about \$300 invested. Consider the two consumers cited above. Both loads are in use at the time of maximum daily load. For the elevator, the central station has to provide an investment of \$9,000, for the ventilator fan \$375. Assuming interest, depreciation and similar charges, and at 10 per cent. we have \$900 to deduct from our gross earnings in the elevator case, before we reach net profits, and \$37.50 in the other case. Suppose we get 10 cents per kilowatt hour in each case, and that the cost of production independent of general expenses, interest depreciation, etc., is 50 per cent. of the gross receipts, etc.

This would mean that if we get 10 cents for each kilowatt hour in both cases, our gross revenue would be \$90 per month in each case, and our gross profit \$45.00 per month, or \$540 per year in each case. But in the elevator case we have interest and depreciation charges of \$900 a year, and hence have actually lost considerable money in supplying this customer, while in the other case we have made a net profit of over \$500 per annum.

We would have to charge more than ten times the rate per kilowatt hour to the elevator, that we charge to the ventilating fan to make the same net profit on \$1.00 of capital invested.

This load factor is a most vital question, and it is the difference in load factors in English and American central stations which makes storage batteries commercially possible there, and impossible here.

The average load factor of an English central station is less than 15 per cent., and even in London in December it is only 33 per cent., while in most American cities the load factor which is 40 per cent. in December will in many cases be above 50 per cent.

This difference is due almost wholly to our motor load, which is an almost unknown quantity abroad. With a 15 per cent. load factor a storage battery may pay, but not with a load factor of 40 per cent., especially when the load factor in our central stations is rising each year.

If central station companies would offer such a discount due to load factor as to warrant their individual customers in installing at his own expense a storage plant which he would charge at the minimum rate per kilowatt hour by a steady current for twenty-four hours per day, and then used this stored energy to

supply his occasional demands for an occasionally very large rate of energy, I believe it is possible that the central station companies, the storage battery companies and the consumers might all derive a profit from the arrangement. I have no doubt that a central station company could afford to make a rate of four cents per kilowatt hour for a continuous service night and day, and make a satisfactory profit, while it would surely lose money in supplying an elevator, such as described above, even at fifteen cents per kilowatt hour.

I believe that the following schedule of rates fairly represents the charges per kilowatt hour that should be made to customers of various load factors.

Load Factor.	Rate per kw. hour in cents.	Resultant gross in- come per annum per kw. of plant.
5	30	\$131.40
10	20	175.20
15	16	210.24
20	13	227.76
25	11.2	245.28
30	10	262.80
35	9.2	281.07
40	8.5	297.84
50	7	306.60
60	6	315.36
70	5.3	325.00
80	4.8	336.38
90	4.4	346.80
100	4	350.40

It must be noticed that this argument would lose most of its force if the maximum load of the consumer did not occur at the time of day when the maximum load was upon the central station; but in elevators, and similar loads which call for their maximum load in starting up every few seconds, then maximum loads will not only occur together occasionally, but this will sometimes occur at the time of maximum load on the central station, and when this accumulated load is put upon the central station, the kilowatts must be there to meet the demand.

ELECTRIC HEATING.

I saw evidences of a very healthy demand for electrically heated devices while abroad. In London the principal central station company is running at its own expense a show room for the education of the public in this line, and several manufacturers of electric heaters told me the demand was very satisfactory, and promised a good future.

THE HEILMANN LOCOMOTIVE.

In France I examined what I considered the most important electrical engineering development of all that I saw. It was the Heilmann electric locomotive. Having been for some years past a firm believer in the merit of this machine, and having been in correspondence with Mr. Brown, Mr. Heilmann's electrical engineer, as to an invention of mine used in this locomotive for the first time on a large scale, I was especially interested in it, and my hearers will please discount as they may think necessary my description of the advantages of a locomotive using my system of control.

The locomotive I saw was the first one built, and was not in service when I was there. It had run 2200 miles commercially, however, and as a result of the performance of this first locomotive which was 600 H. P., there are now building two locomotives of 1500 H. P. each, which it is expected will go into commercial service about June next.

This electric locomotive carries its own central station with it. It is really a complete central station on wheels, with its power used for propelling itself. Speaking from memory, I should say the length over all was about 50 feet. The locomotive is mounted upon two bogies each having four axles, so that the weight of the locomotive is borne by 16 wheels, each of which is about 45 inches in diameter. A platform made of heavy iron girders runs the whole length of the locomotive, and is supported upon two pivots one at the center of each bogie. Upon this platform is mounted the coal, water, boiler, engine, dynamo, etc., so that it will be noticed every pound of material is used upon the drivers and therefore becomes effective for tractive purposes.

The entire weight of the locomotive is 114 long tons; that is, about 15,500 pounds per driving wheel, which is about the same as our standard practice in this country. With a tractive coefficient of .2 this means a draw-bar pull of 50,000 pounds and assuming friction at six pounds per ton, we find that 50,000 draw-bar pull would enable us to pull 1900 tons on a one per cent. grade at a low speed, say 15 miles per hour, and would give us ample draw-bar pull for handling a 200-ton train at any speed thus far seriously discussed.

Most engineers who have heard of the Heilmann locomotive have derisively dismissed it from their minds as a ridiculous monstrosity of a crazy Frenchman, but I have for some time

believed, and am now convinced, that you will in the immediate future be bound to give this machine the most respectful consideration. I find that the impression prevails generally, that the modern steam locomotive is really a very perfect and efficient machine. This I think is far from being true. The efficiency of a boiler depends largely upon how perfect the combustion is, and with forced draft we can realize an efficiency of 80 per cent. with very perfectly designed boilers, provided we do not attempt to burn more than about 40 pounds of coal per square foot of grate surface per hour. But the maximum duty of boilers in locomotive practice such as for the highest speed service, involves the use of nearly 200 pounds of coal per square foot of grate surface, and I need hardly say that forcing the boiler in this way results in a terrible inefficiency. To produce an indicated horse-power in a steam locomotive at highest speeds to-day probably requires at least twice as much coal as is required in first-class stationary or marine boilers. This is the first place where Mr. Heilmann is able to show an economy; he is able to carry a larger boiler, and hence does not have to crowd it to such a wasteful point.

But regardless of an abundant supply of steam from the boiler we find ourselves greatly limited in power for steam locomotive practice at high speed, because of the wire-drawing of the steam, and difficulty of properly exhausting when we run our locomotive at its highest speed. The maximum draw-bar pull obtainable when running at the highest speed, is only about half that obtainable at slow speed, no matter how much steam we have at command or at what cut-off we work. Heilmann avoids this difficulty as we shall see presently.

Another matter of most serious importance is the tremendously destructive effect upon the roadbed and upon the locomotive itself, of the unbalanced vertical component of the motion of the counter-balance weight of the steam locomotive, and also the shouldering effect of the locomotive tending to spread the rails. Probably at least one-third of the cost of maintenance of the roadbed and the locomotive for high-speed service could be traced directly to this destructive "hammer blow" and side thrust. Both of these effects which become very troublesome as we go to the higher speeds, are entirely absent in the electric locomotive.

Having now pointed out the weaknesses of the steam locomotive which develop most forcibly as we increase in speed, I will

describe the construction of the Heilmann locomotive and point out how those difficulties are obviated by the electric locomotive.

The steam engine is compound, well-balanced, and directly coupled on its shaft is the electric generator. A four-pole single reduction motor of the iron-clad type is geared to each of the eight axles, and the motors which are series wound are multiple with each other across the brushes of the generator armature. As the motor field must have a fair degree of saturation to prevent sparking when the locomotive is running light and pulling no train, it will be evident that under all operating conditions, the motor fields are constant, and fully saturated which makes them entirely sparkless. The field of the generator is separately excited by means of a small auxiliary engine and constant potential dynamo, which also supplies the electric lights needed. The engine has a fixed cut-off at the most economical point, say one-quarter stroke and its speed is adjusted by the throttle.

The engine in practice is varied in speed from perhaps 50 to 500 revolutions, and the strength of the generator field from zero to its maximum strength. It will be noticed that all steam used is used expansively at a fixed cut-off, and Mr. Heilmann lays great stress on this, although I myself would prefer an automatic engine running at a constant speed, and I believe that he would, if he could get as good ones abroad as we can in this country. For starting, an almost unlimited torque is secured by gradually increasing the generator field strength and speed, which sends a current through the motors, rising smoothly from zero to that current sufficient to start the motor armature. If we leave the field controller and throttle in this initial position, our train will start smoothly, and will continue to move slowly, using the full current, but producing the current with about 50 volts or one-tenth of the full voltage, and we will be producing this power, about one-tenth of that required at full speed, by a steam engine using steam expansively instead of, as in the steam locomotive, full stroke. But of course we desire to accelerate the train rapidly, so we keep on manipulating the field controller and throttle, until we finally have the engine driving the generator at full speed in a field of full strength, which will of course represent the full power of the locomotive. When we reach a grade requiring three times the torque required on the level, we weaken the field to one-third of its full strength. We will then move up the grade at about one-third

of the speed on the level while using the same power as was required on the level.

It will be noticed that under the electrical arrangement on this locomotive, the electric energy is used in such a manner that its voltage is varied in proportion to the speed desired, and the amperes are in proportion to the torque required, so that the electrical energy produced is utilized in the most efficient manner possible.

Since this method of control of mine has been repeatedly criticized before this INSTITUTE on the score that a generator of such size and type when used as described would spark disastrously, I beg leave to say that I scrutinized most carefully the commutator of the generator which had supplied the current during the locomotive's 2200 miles service and I never saw a commutator and brushes in more perfect condition, and the engineer assured me that under no circumstances had there been any sparking whatever. I regret that my method of control does not fit the generally accepted self-induction theory of sparking, but am forced to conclude that as something is evidently wrong, it must be the theory which fails to agree with the facts.

An electric locomotive of this kind would probably cost for the first few about \$30,000, each being equipped with a 1500-horse-power boiler of our best marine type, and one of our best automatic cut-off compound engines directly coupled to a modern multipolar generator. I believe that a locomotive of this type could be built which would be able to pull 50 per cent. more weight than any of the present steam locomotives, and that it could pull the same weight at 50 per cent. higher speed. I think this type of electric locomotive is the stepping stone between the steam locomotive and the electric locomotive operated from a distant central station.

To properly try the experiment of operating a high speed locomotive of 1500-horse-power from a central station would undoubtedly cost nearly a million dollars. To try it with a locomotive of the Heilmann type would cost not more than \$50,000 and if it proves successful, it is not much of a step to replace the boiler and constant speed steam engine with the moving contact and constant speed electric motor for driving the generator already tested and proven satisfactory.

OBITUARY.

FRANZ SCHULZE-BERGE, Ph. D., [*Associate Member, February 7th, 1890, Member, April 21st, 1891,*] was born January 2d, 1856, in Ober-Cassel, Germany. After graduating from the Gymnasium at Bonn, he studied mathematics and physics in the universities of Heidelberg, and Strasburg, and then worked, principally under the guidance of Prof. von Helmholtz in Berlin. In 1880 he took the degree of Ph.D. in Berlin, for which degree Profs. Kerchhoff and von Helmholtz were his principal examiners. Under the guidance of Prof. von Helmholtz, Dr. Schulze-Berge conducted, after methods of his own, experimental researches concerning the contact potential difference between metals and gases. The theme of his dissertation was of especial importance scientifically, since in physical investigations this potential difference is nearly always present as a disturbing element, as all metals are, generally speaking, in contact with gases.

His investigations involved the greatest nicety of manipulation and his methods evinced great originality. It was for his thesis on this investigation that he received his degree of Doctor of Philosophy.

Almost simultaneously with his work, the results of a similar investigation by another party were published, which disagreed with those obtained by Schulze-Berge. The latter at once prepared another paper in which he proved the correctness of his own conclusions and the error of those reached by the other author.

After graduating in 1880 he passed an examination for Ober-Lehrer and occupied this position at the Louisenstaedtesches Gymnasium at Berlin, and that of Gymnasial-Lehrer at the Gymnasium at Charlottenburg.

He also, during this period became a member of the "Berliner Physikalische Gesellschaft" and as such had charge of the official annual reports on different branches of electrical science, which were published in the *Fortschritte der Physik* edited by the society, and at the same time continued electrical work in the laboratory of Prof. von Helmholtz. It was at this time that he was a co-worker with the late lamented Heinrich Hertz. He next turned his attention to the investigation of the electric conductivity of so-called non-conductors in very thin films (of $\frac{1}{10}$ of a millimeter or less). The results of these investigations and others are published in *Weidmann's Annalen*, vols. xii. and xv. and in the *Sitzungsberichte der Berlin Physikalischen Gesellschaft*, 1880.

In 1887 Dr. Schulze-Berge came to this country and became assistant to Mr. Thos. A. Edison. Perhaps the most notable of his work with Edison was the solution of the problem of duplicating phonographic records which was intrusted to his care. The method employed of producing a conducting film upon the wax cylinder of such a character as not to sensibly obscure or modify the finest harmonics, was the result of long study and experiment and evinced the originality of the man. It was an entire success.

Leaving the employ of Mr. Edison, he retired to Brooklyn, where for the past year or two of his life he was engaged in his own private laboratory in physical investigations of various kinds the results of some of which will doubtless soon be published. One of the results of his recent work has been a rotary mercury vacuum pump, an earlier form of which he described in a paper before the International Electrical Congress at Chicago in 1893. This has been still further improved upon, and adapted to the exhaustion of lamps, but the new form has not yet been described.

Dr. Schulze-Berge had long been suffering from an organic disease, the exact nature of which was not known until after his death. He died suddenly in Brooklyn on March 21, 1894, of diffuse nephritis, in the 39th year of his age.

Personally he was of a very retiring disposition and a man of such extreme modesty, that his nature recoiled from notoriety of any kind. For this reason he was less widely known than he was entitled to be through his natural gifts and his contributions to science. He rarely contributed to the technical press except to give the results of some important investigation. He broke away from this rule which he had made for himself, however, shortly before his death, the occasion being the contribution to one of the electrical journals of a biographical sketch of his friend Heinrich Hertz. This was his last appearance in print.

Though he did not count a very wide circle of personal friends, his manner was so kind, so gentle, and so evidently sincere, that none came within his influence but to love him, to admire him, to respect him, both as a man and a scientist.

ALEXANDER HENRY BAUER, [*Associate Member, February 7th, 1890, Member, April 21st, 1891,*] who since 1882 has been actively engaged in practical secondary battery applications for light

and power purposes, died in New York City, January 15th, 1895, of Bright's disease. He passed away quietly and suddenly, while apparently in full possession of his reasoning faculties. Mr. Bauer who was born in Baltimore, August 9th, 1846, had spent his working life in electrical pursuits, due possibly to hereditary traits, his father, William Henry Bauer, having been in service on the original Baltimore and Washington line of Prof. Morse, and was also a friend and admirer of Prof. Henry. "Aleck," as he was familiarly called by his many old-time friends, entered the service of the Baltimore and Ohio Railroad Company in 1859, as a messenger boy. In that capacity he learned telegraphy, and at the beginning of the civil war, was sufficiently advanced to be assigned to regular duty at the Annapolis Junction office. Up to the year 1864 he was actively engaged as a telegraph operator, in the government as well as railroad employ, in various West Virginia offices, and afterwards entered the service of the United States Telegraph Company at Philadelphia. He subsequently returned to Baltimore, where he was employed by the Bankers and Brokers Telegraph Company, and latterly by the Western Union, where he was appointed manager of the Commercial News Department, which included the "ticker" service. Upon the completion of the lines of the Mutual Union Telegraph Company, he was appointed manager of the Baltimore office, but after the amalgamation of that company with the Western Union, he gave up telegraphy which, in his opinion, no longer offered a field for advancement.

The importation from Europe of 60 cells of the Faure secondary battery in 1882, offered him an opportunity to enter upon what proved to be his future branch in the rapidly growing field of electric lighting. In a paper on "Secondary Batteries for Light and Power," before the INSTITUTE¹, presented May 16th, 1886, Mr. Bauer gave a very interesting history of three years practical experience, based upon the introduction of the Faure battery in electric lighting, street railway and telegraph service. This paper was of especial value at the date when it was written, as very little information upon the subject treated, was accessible. He continued in this line of work with the Electric Storage Company, of Baltimore, and the Electrical Accumulator Company, of New York, until 1888, during which period he became more generally known in the rapidly growing ranks of the elec-

1. TRANSACTIONS, vol. iii, p. 129.

trical fraternity. The introduction of the secondary battery for the lighting of railroad trains led to his appointment, on February 18th, 1888, as electrical engineer of the Pullman Palace Car Company, a position which he held at the time of his death. At the Chicago meeting of the INSTITUTE, June 6th, 7th and 8th, 1892, Mr. Bauer read a paper¹ on "Railway Train Lighting," containing a description of the system used in the Pullman service, together with valuable data as to the cost of lighting, made up from actual records. These two papers by Mr. Bauer are characteristic of the man, and showed how thoroughly he had mastered all the details of the actual merits of the secondary battery for the service with which he had been most prominently identified.

In thus giving to the public through the INSTITUTE, the benefit of his investigations extending over a decade, Mr. Bauer performed a service which is no doubt appreciated by all whose duties have led them in similar directions. He also made many improvements in train lighting, some of which were patented. Recently his headquarters were at Jersey City, where he was enabled to personally supervise the apparatus on such through trains to the south and west as were provided with electric lighting plants. Mr. Bauer had a wide circle of friends who were warmly attached to him, all of whom were deeply shocked by his death, not being aware of the fatal character of his illness. He leaves a widow and a son, William F. Bauer, who following the example of his father and grandfather, is also engaged in electrical pursuits, and who was elected an associate member of the INSTITUTE, April 15th, 1890.

RUDOLF EICKEMEYER, [*Associate Member, September 20th, 1893, Member, April 18th, 1894,*] was born in Altenburg, Palatinate, Bavaria, October 18th, 1831, and was educated at the Polytechnic Institute, Darmstadt, Hesse. In 1850 he came to the United States and was first employed on the Erie Railway, and shortly after in the Buffalo Steam Engine Works. On the first of September, 1854, he established himself in business at Yonkers, N. Y., first as a repairer of tools, and subsequently as an inventor and manufacturer of hat machinery. Mr. George Osterheld, who came from Europe with him, was his partner in this business. Before interesting himself in electrical work in

1. TRANSACTIONS, vol. ix, p. 445.

1878, he had taken out about 150 patents. He continued his electrical experimenting and investigating, at first in the line of telephony, and in 1882 invented the type of dynamo which has since been known by his name. He began its manufacture for commercial use in 1886.

Owing to its compact form and high efficiency, this ironclad dynamo has been found especially adapted for railway train lighting. The motor proved equally desirable for street railway work, and its plan of winding was used in the Edison system. Mr. Eickemeyer devoted his attention especially to the magnetic qualities of his dynamos, and in the course of his investigations in 1887, he devised the differential magnetometer which proved of great service in determining the relative merits of different kinds of iron. Working alone as he did, and deriving his electrical knowledge from books, he naturally felt somewhat diffident as to the merits of his inventions. It was not until he had been assured by Mr. Stephen D. Field, that his electrical machinery was of a superior quality, that he decided to place it on the market. Even as late as 1893, when his inventions were well-known and appreciated, he was loth to admit that his work was worthy of consideration. "I am only a maker of hat machinery" were the words he used when asked about his electrical career. In the city of Yonkers, where he had built up a prosperous business, and among his friends who knew him best, his public spirit and genuine worth were highly respected and appreciated. Mr. Eickemeyer died at Washington, D. C., on January 23rd, 1895.

ON THE UNITS OF LIGHT AND RADIATION.

[See p. 85, January Issue.]

DISCUSSION AT CHICAGO, JANUARY 16th, 1895.

[Mr. S. Arthur Rhodes in the Chair.]

PROF. W. M. STINE:—I would call attention to a movement that is now gaining force amongst the photographers of the country. As the editor of one of the leading photographic journals recently expressed to the speaker, "We are trying to get rid of our worst enemy, daylight." Since daylight is such an uncertain factor in photographic work, the arc lamp is fast coming into use to replace it. Photographers are thus endeavoring to obtain a unit light or condition of exposure for their plates. They have a problem before them similar to that encountered in electric illumination, but one whose applications simplify it to some extent. I mention this fact because the paper just read has some bearing on their investigations.

As an attempt to point out the conditions and relations of unit radiation from a light source, the paper has great merit, and, while the mathematical relations have been so fully worked out by the author and others, yet the attempt to assign a nomenclature to certain unit conditions seems perhaps premature. A portion of the title seems unfortunate. The paper does not deal with the unit of light as in any sense applicable to illumination, but the unit conditions of radiant energy, as applicable to a hot-non-luminous, as well as to a hot-luminous source. To render it applicable to purposes of photometry, the question of the amount of radiant energy from the accepted unit for illumination under the unit conditions here laid down must be determined. It seems that this after all is the vital question, and the subsequent ones of the relations of space radiation could readily be obtained from well-known properties of solid angles. All through the discussion a standard of illumination seems presupposed. But here rests the whole matter. We seem almost further removed from a light standard than ever before. It is the physiological action, or peculiarities of the eye which causes the difficulty. The eye is concerned with the quality of the light rather than the intensity of the radiant energy from a source. Even should we arrive at a standard for illumination, which would evaluate the effect of a given light on the eye, and express this unit in terms of the energy involved, we could by no means employ the conclusions here expressed in such a general sense as to make them applicable to all lights.

The quality of a light being its larger factor, lights of a different character cannot be compared along the lines of simple energy relations; at best we can only compare a single light as affected by space relations. Even should the "light of the

future" be realized, we must still hold it capable of variation and quality. The conclusion is, that the attempt to establish unit space and surface relations for purposes of nomenclature is not well founded. Neither can we hope it will gain general acceptance. The whole matter seems to belong to the sphere of radiant energy, and it is a question of pure physics rather than one applicable to electrical illumination. As such, the conditions have already been worked out and can readily be applied in the restricted sense already pointed out, when occasion demands. It seems ill-advised to confuse a subject dealing only with the pure physics of radiant energy by the application of such terms for units as apply only to questions of illumination, involving but indirectly those of radiant energy.

The desire to establish units for the evident purpose of nomenclature has here reversed the usual and logical order. It seems reasonable to await the establishment of a given unit condition before attempting its nomenclature. We must first of all attain a unit condition of light, or, rather of illumination, if the unit is to have any influence. Then it is probable that the naming of the unit would be all-sufficient. Its space and surface relations can be dealt with by the aid of the usual mathematical relations, without encumbering the process with useless nomenclature.

ADAMS ON FIELD MAGNET FRAMES.

[See p. 99, January Issue.]

DISCUSSION AT CHICAGO, JANUARY 16th, 1895.

[Mr. S. Arthur Rhodes in the Chair.]

MR. EDSON:—Modern dynamos are usually built with wrought-iron field and a cast-iron pole piece, and especially is this construction prominent in incandescent dynamos. In the construction of alternators the iron requires to be very finely laminated for the field pieces, and it is also necessary to cast an iron frame around the laminated pole-pieces. In these two cases the entire use of wrought-iron would not, I believe, be particularly desirable, for the reason that it would be very difficult to make a 1000 H. P. generator in a sufficiently solid manner for carrying the magnetic lines around the circuit, while they can be cast free from blow-holes and made nearly perfect.

For some motors in particular, the cast-iron frame offers some advantages, in that it affords a more solid structure. With wrought-iron, the band would be too thin which would still maintain the proper magnetic conductivity in a good substantial manner, but at the same time we would have a machine, that with a forging of this kind, would be liable to spring.

MR. B. J. ARNOLD:—I think that the points made by the speaker were well taken. It would be impracticable to make wrought-iron field pieces, and the cast-iron serves all the purposes. It is certainly much cheaper to construct, and the increased weight when put into the frame is nominal. From a practical standpoint it would be absolutely impossible to build wrought-iron frames for multipolar machines to put on the market in the present financial state of affairs.

MR. L. L. SUMMERS:—The diagram shows twelve inches to eight inches. I think that if the arms were to be of equal length, that the width would be different. I am more interested in the cast-steel part of the problem. I wonder if any one can give me any information on the cost of cast-steel. There seems to be a marked improvement in the last few years in the making of steel castings. There have been several attempts made in the west here to make steel castings, but I do not know with what success. I had occasion to use steel castings some time ago, and found that they were made in Buffalo. If cast-steel can be turned out at reasonable cost at all, it ought to be a very important advent in dynamo designing, because it would enable frames to be used which the engineer to-day is unable to use on account of the cost of construction.

MR. C. A. PRATT:—I think that the whole subject depends upon the size of a machine. In making small machines for motor purposes there is no question as to the advantage of cast-steel over

cast-iron, especially as such machines must be small and light. On the other hand, in manufacturing large machines, there is an item comes in, which is not thought of in the smaller ones, and that is the amount of tool work. If wrought-iron forgings are to be used, there is much more tool work. Cast-steel is what is used, I believe, on street car motors. They are made here in the west, are perfectly satisfactory, and are made up to about 300 or 400 pounds without any difficulty, at a cost of about seven cents per pound. I think that the cast-steel is quite equal to wrought-iron.

MR. ARNOLD:—The question of tool work comes in largely in comparing cast-iron with cast-steel. The tool work on cast-steel is very much more expensive than cast-iron, especially if there is much planing to be done. It eats up tools and labor much quicker than cast-iron. The question in regard to machines is well taken. For smaller motors the wrought-iron frames are certainly the most efficient, but for larger work, I should say that cast-steel or cast-iron would be the best.

MR. PRATT:—There is a limit to this casting. It is not possible to make a casting larger than 400 or 500 lbs. A representative of the Westinghouse company guarantees to make me anything in cast-steel, and assures me that they can get most any kind of a casting that I want. As to whether they can do it, I do not know as I have not tried them. Five years ago in designing some heavy duty engines I used cast-steel for the cranks. We had some difficulty with the blow-holes on those, but I have no difficulty since, and they tell me that they can furnish steel castings of any desired size. But these castings shrink considerably, and the pattern maker does not know how much to allow for this.

MR. ALBERT SCHEIBLE called attention to the author's diagram and said that so far as he could see the frames were made with a square cross-section. "I doubt," he said "if those proportions would hold good in larger machines of other types. As to the difference in the amount of tool work between wrought and cast-iron, I should think that this would depend upon the difference in the cost of copper in the armature windings."

MR. EDSON:—In connection with wrought-iron, I would say that it has one advantage, and that is, that a dynamo used on shipboard is a very small machine, and must get the greatest output from a pound of copper, or a pound of iron, and here wrought-iron would have an advantage over the other metals. But this would not apply in machines of larger type. In connection with steel castings, I would say that about 18 months ago I had some experience with steel castings, and found that they were full of blowholes. In the cores they were all right, but at the ends where we wanted them to hold firmly we discovered that just at this point they were very unsatisfactory. I have, however, seen some castings since, which were much better than these, and there has doubtless been considerable improvement in their manufacture.

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GEORGE:—In Baltimore, Md., February 4th, 1895. John C. George, late President of the Raleigh Electric Street Railway Company. Mr. George was elected an associate member of the INSTITUTE April 18th, 1894.

NOTICE.

Written discussions of the paper contained in this issue if acceptable, will be printed in the March number if received before March 9th.

The Secretary will esteem it a favor if his attention is called to any errors in either papers or discussion, in order that they may be corrected before printing the sheets for the annual volume.

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Contents of Vol. XII. 1895, as far as Published.

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